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1 and 17, surrounding the centrifuge rotor by annular  
2 seals, 13 and 14, between 18 and bore 106 of housing  
3 107. The concentrated carbon dioxide is removed  
4 through a volute 9, discharging at 110.

5 The enriched methane is removed through a  
6 port, 10, in the hollow shaft 2, and flows at 11 to  
7 another part 110 of the process. Wall 6 in the shaft  
8 separates flows 1 and 11. Auxiliary means to rotate  
9 the shaft is shown at 111.

10 Fig. 2 shows another centrifuge which can be  
11 used to decrease the concentration of carbon dioxide in  
12 a gas mixture.

13 A gas mixture 1', enters the centrifuge 100'  
14 via wall 110' and flows to a nozzle 2', which is  
15 oriented in a generally tangential direction to a  
16 cylindrical rotor 18'. The gas mixture is expanded in  
17 the nozzle to a high exit velocity at 3', in a  
18 direction generally tangential to the rotor. The gas  
19 flows through axial vanes 17', with turbine effect,  
20 which support the rotor from a shaft 16'. Nozzle 2' is  
21 radially offset relative to rotary shaft 16'. The  
22 rotor acquires the circumferential velocity component  
23 of the entering gas.

24 The heavier carbon dioxide is concentrated by  
25 the centrifugal force at centrifuge outer radius zone  
26 4', near outer wall of the rotor 104'. The lighter

1 methane is concentrated at the inner radius zone 5'  
2 near the surface of shaft 16' of the rotor. The  
3 concentrated carbon dioxide stream flows through outlet  
4 passage 7' increasing its pressure. The flow is then  
5 accelerated through a nozzle 8, adding more torque to  
6 the rotor to overcome windage and friction losses. The  
7 concentrated carbon dioxide stream is removed through a  
8 volute 9', discharging at 209'.

9                   The concentrated methane stream flows into an  
10 outlet scoop 10', which faces in generally tangential  
11 relation to the circumferential flow direction to  
12 remove a produced and concentrated lighter gas such as  
13 methane, from the cylinder. The velocity is converted  
14 to pressure by the passage 11', which has an increasing  
15 flow area within wall 111' to diffuse the velocity and  
16 recover the velocity head as increased pressure at 12',  
17 and delivered at 300 to process 301. The concentrated  
18 methane is removed through another volute 12' at the  
19 outer side or end of 111'.

20                   The rotor is supported by annular bearings  
21 13' located between the shaft 16 and bores in end walls  
22 110' and 111'. If sufficient pressure drop is  
23 available between 1' and 3', the shaft may be totally  
24 enclosed; otherwise, a seal is incorporated in the  
25 structure 13', and a power source 301 is provided to  
26 rotate the centrifuge at desired speed.

1                   The pressure within the rotor 18' is isolated  
2    by annular seals 14' and 15' from the low pressure on  
3    the outer side 19' of the rotor, which is required to  
4    minimize frictional losses at the high speed of the  
5    rotor. The concentrated CO<sub>2</sub> in the volute 9', is  
6    isolated from the pressure within the rotor 18', and  
7    the pressure at zone 19' surrounding the rotor, by  
8    seals 14' and 15'.

9                   Fig. 5 shows another centrifuge which can be  
10   used to decrease the concentration of carbon dioxide in  
11   a gas mixture.

12                  A gas mixture 1'', enters the centrifuge  
13   100'' via wall 110' and flows to a nozzle 2', which is  
14   oriented in a generally tangential direction relative  
15   to a cylindrical rotor 18''. The gas mixture is  
16   expanded in the nozzle to a high exit velocity at 3'',  
17   in a direction generally tangential to the cylindrical  
18   rotor. The gas flows through axial vanes 17'', with  
19   turbine effect, which support the rotor from a shaft  
20   16''. Nozzle 2'' is radially offset relative to rotary  
21   shaft 16''. The rotor acquires the circumferential  
22   velocity component of the entering gas.

23                  The heavier carbon dioxide is concentrated by  
24   the centrifugal force at centrifuge outer radius zone  
25   4'', near outer wall 104'' of the rotor. The lighter  
26   methane is concentrated at the inner radius zone 5''

1 near the surface of shaft 16'' of the rotor. The  
2 concentrated heavier carbon dioxide stream flows  
3 through outlet passage 7'', increasing its pressure.  
4 The flow is then accelerated through a nozzle 8'',  
5 adding more torque to the rotor to overcome windage and  
6 friction losses. The concentrated carbon dioxide  
7 stream is removed through a volute 9'', discharging at  
8 209'''.

9                   The concentrated methane stream flows into  
10 another outlet passage 10'', whose inlet 10''' is  
11 located radially inward at the radial location 5''  
12 where the lighter gas is concentrated. The  
13 concentrated methane stream flows through the outlet  
14 passage 10'' increasing it's pressure. The flow is  
15 then accelerated through a nozzle 8''' adding more  
16 torque to the rotor to overcome windage and friction  
17 posses. The concentrated methane is removed through  
18 another volute 9''' discharging at 209''.

19                   The rotor is supported by annular bearings  
20 13'' located between the shaft 16'' and bores in end  
21 walls 110'' and 111''.

22                   The pressure within the rotor 18'' is  
23 isolated by annular seals 14'' and 15'' from the low  
24 pressure on the outer side 19'' of the rotor, which is  
25 required to minimize frictional losses at the high  
26 speed of the rotor. Such seals seal off between 18''

1 and wall 110a''. The concentrated CO<sub>2</sub> in the volute  
2 9'', is isolated from the pressure within the rotor  
3 18'' and the pressure at zone 19'' surrounding the  
4 rotor, by seals 14'' and 15''.

5 To further concentrate the carbon dioxide  
6 stream and the methane stream, the flows at 9'' and  
7 12'' leaving the centrifuge from Fig. 5, can be  
8 introduced to additional like centrifuges, i.e. a  
9 ''cascade'' of centrifuges.. The cascade provides a  
10 method of connecting many centrifuges together so as to  
11 amplify the separation capacity and flow rate of a  
12 single unit.

13 The cascade is typically comprised of a  
14 number of stages, the size of each stage being defined  
15 by the amount of flow that must go through the cascade.  
16 The amount of flow required is directly related to the  
17 desired flow of the product (the stream comprised  
18 mostly of the lighter gas) and its concentration. The  
19 desired concentration, in turn, determines the number  
20 of stages necessary. The product delivery end of the  
21 cascade is called the ''top'' while the waste end is  
22 called the ''bottom''.

23 The cascade is divided into two sections, the  
24 ''stripper'' and the ''enricher''. The enricher  
25 section is that between the feed point (where the  
26 mixture comes in) and the top of the cascade, while the